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The response to and rejection of Brian Ford's *Too Big to Walk*, a 21st century effort to reinstate the aquatic dinosaur hypothesis

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ABSTRACT

In magazine articles, a BBC Radio 4 interview and the book *Too Big To Walk*, Brian Ford argued that the dinosaurs of the Mesozoic were not adapted for terrestrial life, but were aquatic. Bemusement and rejection were expressed by palaeontologists, in part because evidence contradicts Ford's proposal, but also because the aquatic paradigm underwent testing and rejection during the 20th century. Evaluation of the case as presented by Ford reiterates the fact that non-bird dinosaurs as a whole were unsuited for aquatic life; this does not contradict proposals that certain groups (like Spinosauridae) or species (like *Spinosaurus aegyptiacus*) were amphibious or aquatic. Ford framed the reaction to his proposal as a demonstration of the palaeontological community's insistence that outside views are unwelcome and used a 'post-truth' narrative in promoting his hypothesis. Ford relied on the belittling and dismissal of expert voices, the employment of 'alternative facts', inaccurate reporting of pertinent events, and unironic use of terms like 'fake news'. In this article, I review Ford's discussion of the aquatic dinosaur conversation and report events as witnessed via my direct involvement.

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Introduction

Among the most enduring of images in palaeontological history is that of the swamp-dwelling, aquatic brontosaur, prevalent in innumerable sources published between the 1890s and 1980s (Figure 1a). Following a reinterpretation of sauropod morphology initiated during the 1970s (Bakker 1971; Coombs 1975), it has become evident that sauropods were specialised for terrestrial locomotion and had a giraffe- or elephant-like ecology. This is supported by functional morphology, biomechanics, taphonomy, ichnology, isotope geochemistry and other lines of evidence (Dodson et al. 1992; Upchurch et al. 2004; Nicole et al. 2011; Sander et al. 2011; Wilson and Curry Rogers 2012; Hallett and Wedel 2016). Such views do not negate the possibility that sauropods swam, waded or wallowed, or that some species were denizens of wetlands. Nevertheless, sauropods are so well suited for terrestriality that it is worth asking why they were ever considered aquatic.

When Owen (1841) described the first sauropod known to science (*Cetiosaurus* from the Middle Jurassic of England), he identified it as a whale-like animal that swam via use of a crocodile-like tail. The first skeletal reconstruction of a sauropod – that depicting the Morrison Formation's *Camarasaurus*, exhibited in 1877 – provided it with a laterally flattened tail (Taylor 2010). Descriptions of Morrison Formation sauropods published during the 1870s pointed to their retracted bony nostrils, long necks, supposedly weak feeding apparatus and pneumatic vertebrae as aquatic specialisations (Upchurch et al. 2004). Contributing to this interpretation was the view that the Morrison Formation – the world's premier source of museum-quality sauropod fossils – was deposited across a swampy floodplain dominated by lakes and pools. Sedimentological and palaeoecological studies have since shown that the Morrison is better characterised as representing seasonally arid, parkland-style habitat (Dodson et al. 1980), though its size and depositional duration require that generalisation cannot capture its complexity (Maidment and Muxworthy 2019). Nevertheless, it is inaccurate to imagine Late Jurassic North American sauropods (and sauropods in general) as preferentially associated with wetlands.

Sauropods are not the only non-bird dinosaurs framed within an aquatic paradigm. Hadrosaurs – popularly dubbed 'duck-billed dinosaurs' – were also considered aquatic or amphibious across the same period (Figure 1b). John Ostrom (1964), however, showed that functional morphology, biomechanics and taphonomy revealed specialisation for terrestrial life (Forster 1997; Horner et al. 2004). Again, this does not negate the possibility that certain hadrosaurs swam, wallowed, or were associated with wetlands.

Why hadrosaurs were initially considered aquatic is, again, a good question. Several misinterpretations are to blame: that the rostrum was 'duck-billed' and suited for aquatic foraging (preserved rhamphotheca reveals a downcurved bill unlike that of ducks); that the fingers were webbed and formed a paddle (tracks and soft tissues reveal unification of the fingers in a pseudohoof specialised for walking; Figure 2b); and that the tail formed a sculling device (ossified tendons and evidence for massive musculature show that the tail was deep, but thick and not similar to the tails of crocodylians or other amphibious reptiles) (Bakker 1986; McGowan 1992; Forster 1997; Creisler 2007).

A few authors promoted aquatic habits in non-bird dinosaurs for erroneous reasons. Wilfarth (1949) argued that the majority of non-bird dinosaur taxa were aquatic due to a belief that the Mesozoic was a time of 'greater tides' caused by the supposed closeness of the moon (Figure 1c–d), and Ebel (2000) argued that dinosaurs lacking elongate neural spines could not have been terrestrial for biomechanical reasons. Amphibious or aquatic habits have also been suggested for taxa based on anatomical details and/or their palaeoecological settings: examples include *Liaoningosaurus* among ankylosaurs (Ji et al. 2016) and

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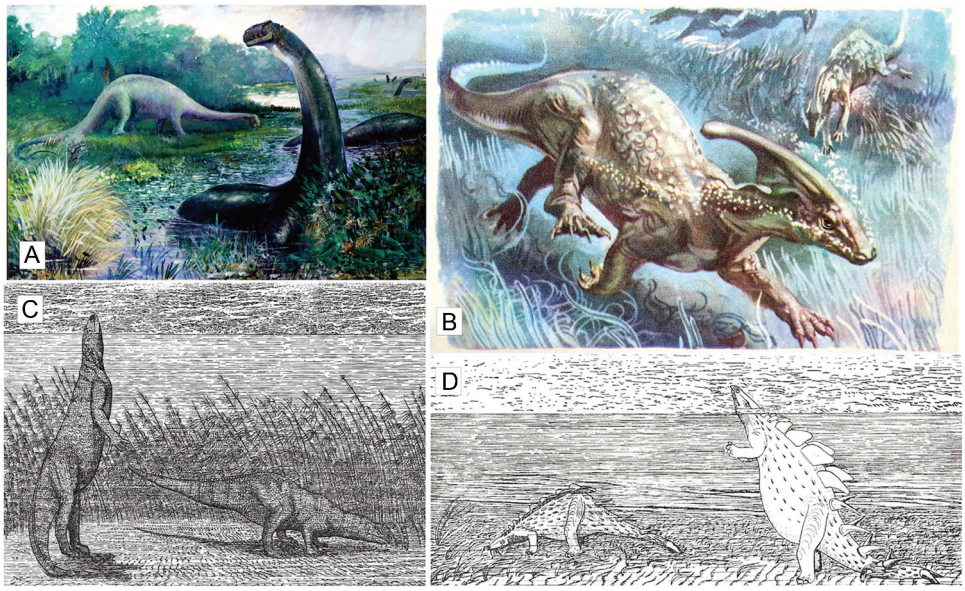

Figure 1. Any claim that an 'aquatic dinosaur' hypothesis might be considered 'new' cannot be taken seriously in view of history. Between the late 1800s and 1970s, sauropods and hadrosaurs were mostly regarded as aquatic or amphibious, as exemplified in illustrations by (a) Charles Knight (from 1897) and (b) Giorgio De Gaspari (from 1971). Some authors proposed that essentially all non-bird dinosaurs were aquatic or amphibious, most notably Wilfarth (1949). Among his most surprising illustrations are those depicting aquatic habits in (c) *Iguanodon* and (d) the stegosaur *Kentrosaurus*.

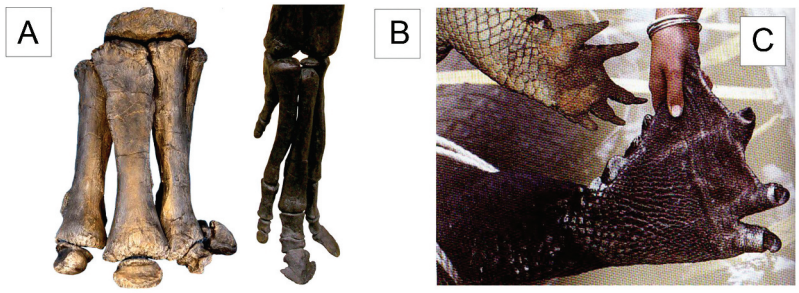

Figure 2. The anatomy of most non-bird dinosaur taxa demonstrates non-aquatic habits. The hands of (a) sauropods like *Brachiosaurus*, and (b) hadrosaurs like *Edmontosaurus* were narrow, compact 'pseudohooves'. Contra Ford (2018), (c) crocodylians have extensively webbed hindfeet. (a) provided by Anthony Maltese, used with permission; (c) provided by David Kirshner and from Grigg and Kirshner (2015); used with permission.

Psittacosaurus and *Koreaceratops* among ceratopsians (Ford et al. 2010; Yuong-Nam et al. 2010). On the basis of analogy with extant animal groups, it is likely that some Mesozoic dinosaurs were amphibious or aquatic and were unusual with respect to the ecology typical of their groups. However, most such proposals are undertested and rely on emphasis of traits that have alternative explanations. The case for aquatic habits in spinosaurid, unenlagiine and halszkaraptorine theropods is more complex, and these groups are discussed further below.

Dinosaur researchers today are familiar with the aquatic paradigm, and awareness of its decline and rejection is part of the history of dinosaur research, retold in popular (Gilbert 1979; Lambert 1983; McGowan 1992; Naish 2009; Norman 1985, 1990, Bakker 1986; Wilson and Curry Rogers 2012) and technical (Dodson et al. 1992; Horner et al. 2004; Upchurch et al. 2004; Taylor 2010) reviews. In addition, the fall of the aquatic paradigm is embedded within discussions of the dinosaur renaissance (Desmond 1975; McLoughlin 1979, Bakker 1986; Wallace 1987; Lauber 1989; Naish and Barrett 2016; Naish 2021).

On 3 April 2012, news media worldwide announced that researcher and author Brian J. Ford had discovered a new truth about dinosaurs: they were not denizens of terrestrial environments, but aquatic and unsuited for life on land. This proposal did not pertain to sauropods and hadrosaurs alone, but – as per Wilfarth (1949) – essentially all non-bird dinosaurs. Ford's hypothesis was reported on BBC Radio 4's *Today* programme and in the *Telegraph* and other news sources. The announcement was timed to accompany the publication of an article in *Laboratory News* (Ford 2012a).

Ford's hypothesis was presented in greater detail in *Too Big To Walk* (Ford 2018), published in May 2018. This is a well-produced book of 516 pages, released by one of the world's most respected publishers. Successful promotion and distribution meant that it was visible in outlets worldwide and remains so at the time of writing (September 2023). An additional round of publicity occurred in May 2019 when the media carried the story that non-bird dinosaurs owed their extinction to the disappearance of 'sex lakes'. This suggestion – discussed by Ford (2018, pp. 356–357, 457–458) and popular with UK tabloids – was disseminated in order to promote the 2019 edition of *Too Big To Walk*. This second edition contains updates and corrections and is cited here as a distinct work (Ford 2019).

Aims and objectives

This essay is not a thorough evaluation of the aquatic dinosaur hypothesis. Nevertheless, it is integral to my argument that the hypothesis is considered poorly founded and falsified, and for that reason brief discussion is presented below. The hypothesis is a contradiction to scientific consensus and can only be endorsed if one ignores or rejects information relevant to such fields as functional morphology, sedimentology, palaeoecology and palaeoclimatology.

Given the currency of concerns about the spread of pseudoscientific views (e.g. Kaufman and Kaufman 2019; Gordin 2023), it is worth documenting how something as innocuous and trivial (in the sociocultural sense) as a debate about the biology of dinosaurs occurred. My aim is to discuss how Ford presented his claims and what tactics he used, and how his proposal was received and rejected. I report not only print communications, but also those delivered at meetings and across social media.

'Who the hell is 'Prof. Brian J. Ford'?'

Immediately upon the publication of Ford's opening volley (Ford 2012a), those familiar with dinosaur research expressed disdain and disbelief across social media. Probably few were aware who Brian J. Ford is; Ford (2018, p. 335) mentioned but did not cite the 4 April 2012 Metafilter article 'Who the Hell is "Prof. Brian J. Ford"?'. It is therefore appropriate to discuss Ford's history of work, and on this point comprehensive information is available via Ford's website (brianjford.com), Wikipedia, wikiwand, IMDb and other sources.

Ford is a science writer and independent researcher who holds affiliations with numerous bodies, including the Royal Microscopical Society, Linnean Society of London, Cardiff University and University of Leicester. As noted in a biographical section at brianford.com, he left formal education after becoming 'dissatisfied with the direction science was taking', thereafter becoming an independent researcher with his own laboratory. A career in broadcasting and science promotion occurred alongside Ford's research on microscopy and microbiology; his more than 20 books (published between 1969 and 1993) cover such topics as secret military weapons, food science, microbiology and science in general. As of the early 2020s, Ford remains an active writer on spectroscopy, societal approaches to science, cell biology, forensics, biohazards and more. He is also a public lecturer with a busy schedule.

Ford's interest in dinosaur biology was announced in *Laboratory News* in March 2012, this being antecedent to his article ('A prehistoric revolution') of April 2012 (Ford 2012a). His decision to publish on dinosaurs represented the culmination of decades of consideration (Ford 2018, pp. 318–329), the primary catalyst being his viewing of a computer generated *Spinosaurus* in the 2011 BBC series *Planet Dinosaur*.

Ford's efforts in outreach and education – major strands of a long career dedicated to the promotion of science – are commendable. It is, alas, difficult to be generous about Ford's efforts to reinterpret dinosaurs. Four charges can be put against him in connection with this work. Firstly, the catalyst for Ford's development of his aquatic dinosaur hypothesis is personal incredulity, and a criticism levelled at him throughout the conversation is that adequate support for the hypothesis was never offered. Secondly, Ford has consistently eschewed fair reference to the aquatic hypothesis of the nineteenth and twentieth centuries, claiming to be presenting a 'new science of dinosaurs' (Ford 2018, 2019), even though his writings explored familiar, extensively tested old ground. Thirdly, any reinterpretation of dinosaur biology requires basic familiarity with these animals. Ford has admitted to being naïve and inexpert on dinosaurs, and a consequence is that he has claimed 'wins' for the hypothesis when the findings are irrelevant (in a Facebook post of 16 December 2021 discussing a Permian synapsid, for example). Fourthly, Ford's writings promote a bellicose narrative in which palaeontologists are described as incompetent, delusional, and uninterested in the investigation of new claims and discoveries (Ford 2012b; Ford 2018, 2019). He has written in the tone seen elsewhere among conspiratorial 'truthers' (Montell 2021), and the rejection of his hypothesis has been cited as evidence that palaeontologists are only invested in maintaining consensus (Ford 2012b; 2018; Fallon 2019). Nonetheless, palaeontologists agree that the aquatic dinosaur hypothesis has been rejected due to familiarity with the arguments, awareness of relevant data and the tests performed on it, and dissatisfaction with Ford's assertions.

The aquatic dinosaur hypothesis is not viable

The primary argument behind Ford's hypothesis is personal incredulity, since he has noted that dinosaurs 'make no sense' (Ford 2012a, p. 25; 2018, p. 237) according to his intuition. Two specifics were offered to verify his claim, albeit only as assertions. The first is that bipedal theropods would suffer from extreme oscillation about the vertical axis (yaw) during terrestrial locomotion (Ford 2018, pp. 293–294, 384–385). Nowhere is it explained why this should be so. Like extant long-tailed birds and bipedal pangolins, it should be assumed that a long-tailed non-bird theropod could walk or run while maintaining balance and correcting for yaw by modifying limb posture and foot position. Trackways do not reveal indications that the animals had issues with yaw, and analyses of locomotion and dynamics demonstrate agility and an ability to deal with inertia (Henderson and Snively 2004).

The second specific (Ford 2018, p. 299) is that dinosaurs were too big for terrestrial life. Many sauropods exceeded 10 tonnes, and giants exceeded 80 tonnes. These were exceptional, and the majority of non-bird dinosaurs weighed less than 1000 kg, making Ford's objection irrelevant. Regardless, the size of the biggest dinosaurs has resulted in efforts to calculate limb bone and cartilage loading, the results showing that even they were capable of bearing weight within the safety margins of their tissues (Alexander 1989; Taylor 2005; Henderson 2012).

Ford (2012a, p. 25; 2018, p. VIII, 383) also claimed that the dinosaurian tail is too heavy and energetically costly for terrestrial life. These assertions are refuted by anatomy: ligaments and interlocking joints assisted in maintaining the tail's semi-horizontal pose, just as they do in extant animals with elevated sections of the vertebral column (e.g. Nalley Thierra et al. 2023). Furthermore, the tail is not a dead weight but highly muscular and the anchor for the caudofemoralis longus, the largest muscle in the body. There is no reason to assume that the tail was 'too costly'.

Looking broadly at dinosaur lifestyle, the 'form leads to function' principle demonstrates terrestrial habits for the majority of non-bird dinosaurs (Figure 3). Terrestrial traits of the dinosaur skeleton include robust limb joints, large limb girdles, and reinforced and lengthened sacral regions. These animals lack the streamlined body shapes, reduced sacral regions, reduced limb girdles, paddle- or flipper-like limbs, paddle-like tails, and pachyostotic or osteoporotic bones of aquatic and amphibious tetrapods. Proportionally small, compact hands are present in sauropods and hadrosaurs (Figure 2a–b), dinosaurian limbs are typically pillar-like; eyes and ears are not dorsally located; and tails are typically thick and rounded in cross-section. The dorsally sited bony nostrils of sauropods do not appear to be indicative of nostril position in life: other evidence reveals a conventional location close to the mouth

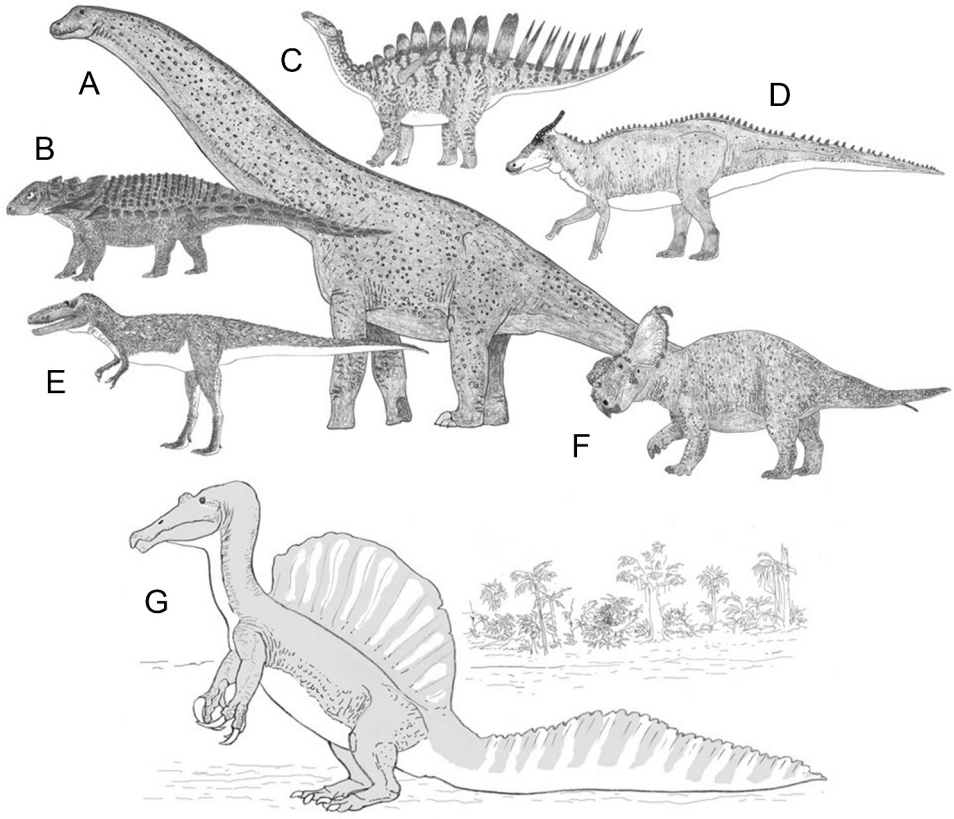

Figure 3. There is little doubt that non-bird dinosaurs of many species were capable waders and swimmers. They were not, however, adapted for aquatic life, as is obvious from their shapes and proportions. (a) *Alamosaurus*, a sauropod; (b) *Edmontonia*, an ankylosaur; (c) *Miragaia*, a stegosaur; (d) *Saurolophus*, a hadrosaur; (e) *Alioramus*, a theropod; and (f) *Pachyrhinosaurus*, a ceratopsian. Unusual proportions, thick-walled bones and other features suggest that some taxa – most famously (g) *spinosaurus* – were amphibious or aquatic. Illustrations by Darren Naish.

(Witmer 2001). Non-bird theropods and sauropods were pneumatic, with an air sac system extending into the limb girdles and limbs in some taxa. This would have made some species highly buoyant (Henderson 2004), a fact at odds with the reduced skeletal pneumaticity present in aquatic birds (O'Connor 2009).

This anatomical perspective is augmented by palaeoenvironmental, lithostratigraphic, taphonomic and ichnologic data. The anatomy and sedimentological context of dinosaur tracks shows that they were made by terrestrial animals in terrestrial settings, mostly lake edges and coastal fringes. Tracks purportedly made by swimming dinosaurs were used by Ford (2018, pp. 392–394) to support his hypothesis but the fact that dinosaurs swam does not demonstrate aquatic habits. Isotopic data from non-bird dinosaurs reveal terrestrial isotopic signatures, an exception being provided by spinosaurids (Amiot et al. 2010). The terrestrial context of dinosaurian nesting behaviour (Hallett and Wedel 2016, Naish and Barrett 2016) is also in keeping with terrestrial habits.

Ford's model requires the reinterpretation of palaeoenvironmental data relevant to the strata where dinosaur fossils occur (Ford 2018, pp. 410–411, 438–440), and Ford stated that a dialogue with palaeoclimatologist William Hay resulted in a paradigm-busting manuscript. No such published work exists, but Hay (2017) includes a section on dinosaurs. This repeats Ford's assertion that the dinosaurian tail would be maladaptive before noting that 'Much of the biology fits well with Ford's "aquatic dinosaur" hypothesis' (Hay 2017, p. 16), an arguable claim. On Cretaceous habitats, Hay (2017, p. 5) proposed that 'the land surfaces were much wetter than has been thought, with meandering rivers and many oxbow lakes providing habitat for large dinosaurs'. Even if Hay's model is correct, 'presence of wet land surfaces, rivers and lakes' is not synonymous with 'ergo, aquatic dinosaurs'. In any case, modern Cretaceous climate models do not agree with Hay's generalisations: he relied on an unrealistically low (<500 m) continental elevation and did not take account of more recent modelling of cloud physics and CO_2 simulations (A. Farnsworth, pers. comm). Rather than generalising that the Cretaceous land surface was a continuously hot, wet, humid, balmy lowland, recent studies find support for dynamic temperature variations, reduced sea levels and polar ice sheets across the Cretaceous (Cavalheiro et al. 2021; Wang et al. 2023).

Critical response

The April 2012 announcement (in both *Laboratory News* and BBC Radio 4's *Today* show) of Ford's hypothesis was reported across global media (e.g. *Daily Mail*, the *Telegraph*, Fox News, Sky News) where it was mostly treated as scientifically legitimate. In view of the history of dinosaur research, it is unsurprising that the response from many academics was incredulity, in part because events occurred close to April Fool's Day. Ford regarded this coverage as 'encouraging' and noted that '[most reports] were accurate' (Ford 2018, p. 331). Following the *Today* show feature, sauropod expert Mike P. Taylor sent a letter and petition to BBC complaints requesting retraction. In their response, the BBC emphasised the lighthearted nature of the feature and their inclusion of palaeontologist Professor Paul Barrett as an opposing voice to Ford's.

Additional critical responses to the Radio 4 feature appeared on blogs, including skepticblog and the *Smithsonian Magazine* blog.

The appearance of Ford (2012a) also resulted in a negative published response, requested by the editor on 3 April 2012, in *Laboratory News* (Naish 2012). This concluded that 'Ford's proposal is so wrong-headed and contrary to evidence that it hardly seems worth responding to' (Naish 2012, p. 32).

31 May 2018 saw the publication of *Too Big To Walk* (Ford 2018) (Figure 4). This is a remarkable book, not for the hypothesis it claims to explore but for its being an over-long exploration of tangents, asides and irrelevancies. It reads like an exercise in padding, with sections on solar eclipses (Ford 2018, pp. 138–140), the La Brea tar pits (207–209), attempts to estimate the age of the Earth (238–244), the Loch Ness Monster (432–434) and the recounting of email exchanges about draft manuscripts (454–455). Ford's proposal that dinosaurs were aquatic is not introduced until page 282. The book includes quotes from dinosaur specialists including Paul Barrett (331–332), David Norman (336), Paul Upchurch (338), and Donald Henderson (380–382), all of whom express disagreement with Ford's hypothesis, all of whom are dismissed as unable to see the brilliance of Ford's logic. It is unlikely that *Too Big To Walk* benefitted from specialist review, since errors of fact and spelling are present throughout.

Prior to publication, the event 'Were Dinosaurs Too Big? Discussing Dinosaur Evolution', organised by Collins in co-operation with the London Fortean Society (LFS), occurred at Conway Hall, London, on 15 May 2018. This was the launch for *Too Big To Walk*, though only one copy was sold and this was returned on the day for a refund (pers. obs.). Following an introduction from Scott Wood of the LFS, Ford gave the presentation 'Were Dinosaurs Too Big to Walk'. This was followed by one from myself, titled 'A Vast Quantity of Evidence Confirms That Non-Bird Dinosaurs Were Not Aquatic'. A question and answer session ended the event. Interest was expressed worldwide as evidenced by tweets collated at Twitter/X under #FordvNaish. A check (they are visible as of 25 September 2023) reveals widespread incredulity about the brash nature of Ford's presentation, disbelief at the weakness of his arguments, and agreement with the points made during the presentation that countered Ford's. The event was reviewed and discussed on podcasts and blogs.

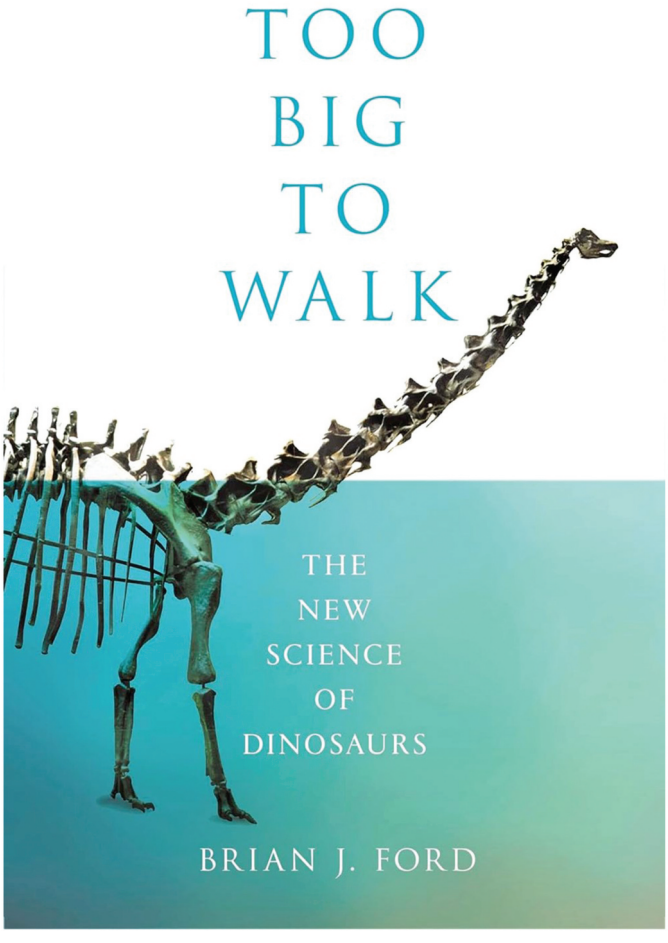

Figure 4. The primary venue for Ford's aquatic dinosaur hypothesis is the 2018 book *Too Big to Walk*, though the hypothesis is only briefly discussed in this 516-page tome.

As expected for a professionally published work making a controversial claim, *Too Big To Walk* was reviewed at numerous venues. It is difficult to find one that is neither critical nor satirical. A June 2018 review at Inquisitive Biologist notes that the book's historical review is 'old hat', that the content devoted to the aquatic hypothesis 'is some 30 pages of opinion, speculation, and [reference to] the occasional cherry-picked publication' and concludes that '[t]his book is frankly bizarre. Not only does it peddle an uninformed, speculative idea, it does so in a poor fashion, with lots of irrelevant asides rather than the balanced overview'. The Natural History Book Service took the unusual (if not unprecedented) move of adding a *caveat lector* to their entry on the book. This noted that it is 'generally not taken seriously, being at odds with a large body of evidence'.

As of September 2023, *Too Big To Walk* scores 3.3 out of 5 on Amazon, a figure lower than that associated with 'good' books, and one associated with neutral views rather than negative or positive feelings (according to a 2017 overview at Rosepoint Publishing). At Goodreads (generally considered more authoritative and reliable in the quality of its reviews and scoring system), the book scores 2.47 out of 5 (as of September 2023). Both sites reveal an unusually high percentage (20% at Amazon; 34% at Goodreads) of one star reviews, and a conspicuous number of reviews that make accusations about the book and its author. Positive reviews exist, some of which praise the author for being unafraid to challenge orthodoxy, others of which describe the book as an entertaining review.

At this point in the book's life, it appears fair to conclude that reviews and scores are indicative of *Too Big To Walk*'s reception. *Too Big To Walk* has not been warmly received, nor deemed persuasive or compelling. Google scholar (as of September 2023) lists a single citation, this being an article on the Gobi Desert in the online encyclopaedia scientiaen.com. The book has been roundly criticised, even by laypeople with no connection to palaeontology, and recognised as intellectually problematic and unsatisfying. Of incidental interest is that two lengthy, critical reviews, submitted by palaeontologists Mark Witton and Chris Tijani Barker, were removed from Amazon (pers. obs.), though it is possible that this reflected a policy decision rather than censorship.

Inappropriate generalisation: the use and abuse of *Spinosaurus*

Any familiarity with Mesozoic dinosaur research will reveal that possible aquatic behaviour is one of the most contested issues in the field, but only as it pertains to *spinosaurids* (Ibrahim et al. 2014, 2020a, 2020b; Henderson 2018; Hone and Holtz 2021; Fabbri et al. 2022; Sereno et al. 2022; Myhrvold et al. 2024) and halszkaraptorines (Cau et al. 2017; Brownstein 2019; Cau 2020; Fabbri et al. 2022), a bird-like group allied to *Velociraptor* and its kin.

Halszkaraptorines appear to have superficially recalled long-tailed, short-winged geese in life, and their tooth shape, snout form, limb proportions and body shape suggest specialisation for swimming and diving; this view has been contested (Brownstein 2019), albeit via erroneous argumentation (Cau 2020). A wading, piscivorous lifestyle has also been suggested for the allied unenlagiines on the basis of tooth form and an elongated face (e.g. Novas et al. 2009).

The real area of controversy concerns spinosaurids, and *Spinosaurus* specifically. The case for an aquatic *Spinosaurus* was made on the basis of its crocodile-like facial skeleton with retracted external nostrils and semi-conical teeth, short hindlimbs, flattened ungual phalanges, thickened bone walls and an unusually flexible tail (Ibrahim et al. 2014). This interpretation of *Spinosaurus* did not emerge *de novo*, instead representing the culmination of four decades in which spinosaurids as a whole were regarded as aquatic or amphibious (Taquet 1984; Charig and Milner 1986, 1997; Paul 1988; Buffetaut 1989; Bakker et al. 1992; Špinar and Currie 1994; Holtz 2007; Amiot et al. 2010; Bertin 2010): '*Spinosaurus* and *Baryonyx* may … have been more or less amphibious' (Buffetaut 1989, p. 86); 'The long crocodile-like snouts of spinosaurs indicate piscivorous habits … and hence these giant theropods may be a radiation of marine predators analogous to that of the early seals and toothed whales of the Tertiary' (Bakker et al. 1992, p. 23); '[*Spinosaurus*] may have … spent much of its life in water' (Špinar and Currie 1994, p. 96). It must also be noted that Ibrahim et al.'s (2014) interpretation of *Spinosaurus* as an aquatic pursuit predator has been contested and an alternative model posits it as an amphibious wader (Henderson 2018; Hone and Holtz 2021; Sereno et al. 2022; Myhrvold et al. 2024).

It is thus highly perplexing that Ford (2018), pp. 399–400) claimed intellectual priority on the concept of an aquatic *Spinosaurus*, and even made efforts to have a charge of intellectual theft investigated by the journal *Science*. These were directed at Paul Sereno rather than at the first author of the paper – Ibrahim et al. (2014) – that was the focus of Ford's interest.

In summary, specialists agree that spinosaurids and some other unusual non-bird dinosaurs were amphibious or potentially aquatic (Naish and Barrett 2016, Naish 2021, Benton 2023, Nabavizadeh and Weishampel 2023). It is erroneous to state, as Ford (2012a, 2012b, 2018, 2019) has, that conclusions made about these groups can be applied to non-bird dinosaurs as a whole. In addition, uncertainty surrounds the palaeoecology of *Spinosaurus* and claims of it being fully aquatic are far from universally accepted; it may have exhibited a lifestyle better described as amphibious or semi-aquatic (Hone and Holtz 2021).

Dinosaurs in a 'post-truth' world: alternative facts and inaccurate reporting

A concern relevant to democracy, health, education, science literary, environmental conservation and climate is that people adopt views at odds with those of mainstream science when sufficient societal pressure exists. This is prevalent given the rise of 'post-truth' movements in which people are encouraged to distrust or ignore qualified experts. Experts disagree on when in the life cycle of a pseudoscientific movement action should be taken, since they evolve in wedge-like fashion and do not appear problematic in their early phases. Within the context of misinformation spread about the Covid pandemic, issues of global democracy and geopolitics and the 'Alternative Influence' network argued to propagate right-wing ideology, a debate about palaeobiology could be considered trivial. Nevertheless, Ford's use of characteristic 'post-truth' techniques (Fallon 2019; Kaufman and Kaufman 2019) should be emphasised.

Ford claimed (including at the Conway Hall event) that he wished for fair debate on the aquatic dinosaur hypothesis: 'I had imagined that the "aquaticists" would line up with the "anti-aquatic movement" and the known facts would be aired, so that we could see which view was probably correct' (Ford 2018, p. 335). This quest for fairness is not reflected in Ford's derogatory comments about palaeontologists (Ford 2012a, 2012b, 2018, 2019), nor his statements about palaeontologists being 'wrong' and 'misguided', nor his proclamation that ' … in paleontology … reputations rest on religious adherence to convention, and you challenge fashionable faith at your peril' (Ford 2012b, p. 131). Indeed, part of Ford's aquatic dinosaur narrative concerns the reaction of the palaeontological community: Ford 2012b, 2018, 2019) stated that the hostile reception it received was unjust, and reflected the entrenched position of the palaeontological community, its unwillingness to change, and its rejection of outsiders (e.g. Ford 2018, VIII – IX, 253). Comparisons with Galileo were made; Ford objected to this at times (Ford 2012b, p. 129, 2018, p. 332) but used it at others (Ford 2012b, p. 131). Ford (2018, p. X) unironically used the terms 'establishment academics' when characterising working scientists and 'fake news' when describing scientific announcements (Ford 2018, p. XI).

Despite these insinuations, dinosaur research has moved in surprising directions over recent decades, and the community has accepted discoveries and hypotheses with both fairness and appropriate scepticism. Examples include the finding that melanosomes provide information on original pigmentation (Zhang et al. 2010), the discovery of feathers in coelurosaurian theropods (including large tyrannosauroids) (Xu et al. 2012), and work showing how some (or many) dinosaurs laid leathery-shelled eggs (Norell et al. 2020). A hypothesis that overturns the consensus on dinosaur phylogeny (Baron et al. 2017) has been appropriately evaluated in follow-up publications. It is also not true that 'outsiders' have been rejected, since newcomers, novices and amateurs have made notable contributions, a point made by Ford (2018, p. 59) himself. Restated, Ford's complaint is that palaeontologists present dishonest and biased contributions to scientific discourse and cannot be trusted, in contrast to the perspective promoted by himself. This narrative promotes rejection of expertise in classic 'post-truth' style (Fallon 2019; Kaufman and Kaufman 2019).

Two additional techniques used by Ford (2012a, 2018, 2019) are consistent with a 'post-truth' approach. The first is the use of assertions – sometimes offered as corrections to points made by palaeontologists – that are themselves wrong, a tactic recalling the 2017 'alternative facts' used by the Trump administration. The second is the inaccurate reporting of events relevant to the conversation.

On 'alternative facts', I offer the following four examples. (1) Ford (2018, pp. 274–276) proclaimed that mass estimates for sauropods have been reduced in order to make them 'look more acceptable' within the terrestrial paradigm. In reality, estimates have changed as techniques have improved and as dinosaur anatomy has become better understood (Henderson 2012). (2) When referring to the phylogenetic connection between birds and other dinosaurs, Ford stated that both 'share an ancestor' (Ford 2018, p. 338) and that birds 'descended from evolutionary stock distantly related to dinosaurs' (431). This is incorrect: birds are theropods, nested within the dinosaurian radiation. (3) Ford (2018, p. 339) argued that those criticising the aquatic dinosaur model 'are not very good at zoology' since they opined that dinosaurs – if aquatic – 'would have evolved limbs that were paddle-shaped, possessed webbed feet, and tails with fins for sculling'. Ford (2018, 2019) pointed to crocodylians as a counterpoint. 'Are crocodiles'

extremities paddle-shaped, and their digits webbed? Certainly not – crocodiles have claws. Are their tails finned for swimming? Indeed, they are not' (Ford 2018, p. 340). The same point is made elsewhere in the book (Ford 2018, pp. 313, 375, 438). The hind feet of crocodylians are significantly webbed (Figure 3c) and the tail is laterally compressed, its distal part forming a deep blade with a tall row of scales (Grigg and Kirshner 2015, p. 144). (4) Ford (2018, p. 451) described *Lystrosaurus* as a dinosaur relevant to the end-Cretaceous event, and as a discovery from the U.S.A. pertinent to E. D. Cope and O. C. Marsh's exploitation of the American West (Ford 2018, p. 136). *Lystrosaurus* is a Permo-Triassic synapsid, initially described from South Africa, unknown from North America, and with no relevance to the end-Cretaceous event nor the Cope-Marsh 'Bone Wars'.

Events relevant to the publication of Ford (2018) are reported in the second edition (Ford 2019). In his discussion of the May 2018 Conway Hall event, Ford (2019, p. 461) described Naish as having 'reiterated the standard view' when discussing dinosaur biology and lifestyle. This is inaccurate given that Naish's talk detailed Ford's claims and showed how they were wrong or based on misinterpretation. Ford (2019, p. 461) further noted that 'Those attending remarked on the lack of objections to the aquatic dinosaur theory raised by those attending' [*sic*]. This is also inaccurate given that the presentation was targeted to counter the specifics of the hypothesis. In addition, Ford's implication that the event should have resulted in the raising of 'objections' mischaracterises the event: there was no format in which Ford's hypothesis might be discussed beyond the initial presentations, and the question and answer session devolved into observations on Ford's role as a contrarian, and on observations contradictory to the aquatic hypothesis. One audience member pointedly accused Collins (members of whom were present in the front row of the audience, including publishing director Myles Archibald) of exercising unsound judgement in giving Ford the opportunity to publish his book. Archibald is credited by Ford (2018, p. 452) as having a personal hand in the publication of *Too Big To Walk* and noted as being 'an old friend' who 'was very positive about putting all my investigations into print' (Ford 2018, p. 452).

A
WHAT THE..?
JUST WHEN YOU THOUGHT IT WAS SAFE TO STAY OUT OF THE WATER
B
Your food is on land, you lay your eggs on land, you're appallingly constructed for an aquatic lifestyle... So tell me again, why are you doing this?
C
LEMME SPLASH!
2 big 2 donk
LEVEL SELECT
INFO

Figure 5. Ford's aquatic dinosaur hypothesis has been mocked across social media and in online entertainment. This is evident from (a-b) cartoons created by artist and designer Gareth Monger, and (c) Samantha Turner's online game *Lemme Splash! An Erotic dinosaur Simulator*.

Of incidental note is Ford's description of the occasion in which a '*Scientific American* blogger' attended one of his lectures in Singapore. In the first edition, this blogger is named as Riley Black (Ford 2018, p. 406) while in the second they are named as Darren Naish (Ford 2019, p. 406). Neither person attended Ford's lecture in Singapore. A video of the event that Ford shared online does not show me, despite Ford's assurance that it does.

Some part of the response to Ford's hypothesis occurred on social media, Twitter/X in particular. In connection with the Conway Hall event, Ford (2019, p. 462) noted that it 'generated hundreds of hostile remarks', the implication being that he was unfairly besieged. If there was hostility, it was due to dissatisfaction with Ford's case and style of argumentation.

Finally, on inaccurate reporting, Ford has noted (Facebook, January 2020) that 'younger palaeontologists love [the aquatic dinosaur hypothesis], but the older ones are hidebound by what they've insisted must be right all their lives'. All responses to Ford's hypothesis I have seen – from junior colleagues as well as senior ones – were critical, highly critical, or mocking in tone. A request for opinions from junior colleagues (via Twitter/X: @TetZoo, 8 January 2020) confirmed suspicions. The 45 responses include the following:

- 'I get the impression that he's not actually spoken to any of these "younger palaeontologists". If he had, he'd be quite aware of a rather different response to the one he's describing'.
- 'Whenever I see his book in bookstores, I cringe at the thought of someone reading, and actually believing, this nonsense. It's very damaging to the already fragile public perception of dinosaurs'.
- 'I like how he thinks current palaeontologists are cowed by tradition when his idea was mainstream in the early 20th century. And it was shown not to be true and we moved on. Ford is the one hidebound by tradition here, to an absurd degree'.
- 'Unless he's mistaking ironic memes and light-hearted mockery for genuine praise, then no, younger palaeontologists don't love him at all. Some of the harshest criticism comes from my demographic, because despite his insistence he represents the regressive attitude most of us hate'.

Conclusion

More than 10 years since its publication (Ford 2012a, 2012b), Brian Ford's aquatic dinosaur hypothesis has failed to win adherents and has been contested at every turn. This is despite the removal of critical reviews of *Too Big To Walk* on aggregate websites. Ford's argument has failed to win traction due to being based on personal incredulity and vague assertion, and to a preponderance of contradictory data (Naish 2012). Ford's (2012a, 2018, 2019) claim that he owns intellectual priority on a suggested aquatic way of life for *Spinosaurus* is invalid, and his implication that an aquatic *Spinosaurus* proves aquatic habits for non-bird dinosaurs in general is a non sequitur. Not only has Ford's hypothesis been rejected, it has been mocked (including in cartoons and the online game *Lemme Splash! An Erotic Dinosaur Simulator*) and mostly regarded as unworthy of serious consideration.

The populist, conspiratorial undertone to Ford's writings on the aquatic dinosaur hypothesis (Ford 2012a, 2018, 2019), in which he is framed as a 'lone truther' crusading against orthodoxy, is uncalled for. The claim that palaeontologists are dogmatic and inflexible ignores the dynamic nature of the field, and the rejection of Ford's hypothesis is due both to dissatisfaction with his proposal, and familiarity with data that supports the consensus, terrestrial view.

Several aspects of Ford's argument are similar to the 'post-truth' tactics used by post-2016 politicians in their efforts to instal an alternative interpretation of reality. A tone of assured self-confidence is present throughout Ford's writings on the aquatic dinosaur hypothesis (Ford 2012a, 2012b, 2018, 2019), and palaeontologists are derided as biased, untrustworthy and uninterested in the examination of novel hypotheses. Ford (2018) also employed 'alternative facts': incorrect statements claimed to bolster his case and replace those otherwise considered correct. In addition, events and statements are inaccurately reported by Ford (2019), and the terms 'establishment academics' and 'fake news' were used without an intended sense of irony when describing scientific announcements (Ford 2018, p. XI).

Ford's reliance on establishment connections in the promotion of his aquatic dinosaur hypothesis (Ford 2018, pp. 452–454) revealed him to be more embedded within 'orthodoxy' than those he criticised. This is emphasised by the publishing of *Too Big To Walk* by Collins, giving Ford one of the best publishing, marketing and distribution deals a party could have. Ford framed *Too Big To Walk* as being from an outsider, but it might be the 'most mainstream' book on dinosaurs ever published. The entire affair is an unfortunate denouement given Ford's prior body of work and reputation as a science populariser.

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